SDSU Extension

iGrow Soybean

BEST MANAGEMENT PRACTICES

Chapter 48:
Soybeans, Salinity, and Sodicity

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The purpose of this chapter is to discuss the hazards associated with salt-affected soils and to present guidelines for reducing the impacts of salts on soybeans production. South Dakota has many soils that are impacted by either high sodium (sodic) or high salts (saline), or by both high sodium and salts.

Salt problems are often discovered in low elevation areas. In the spring as the soil dries, these zones may appear white. For sodic soils, extreme care must be used. High sodium has the added problem in that it can greatly reduce water infiltration. If a sodium problem is suspected, a soil sample should be collected and a water extract from that soil analyzed for Na, Ca, and Mg. Based on this value, the sodium absorption ration (SAR) should be calculated. If the SAR is greater than five, the long-term goal should be to prevent further degradation.

Correct identification of the problem is critical for improving profitability and long-term sustainability. Selected guidelines are provided in Table 48.1.

Table 48.1. Rules of thumb about saline and sodic soils.

Saline soils have high salts.

- *High levels of salts can reduce soybean seed germination and yields when the EC of saturated extract of soil exceeds 5 dS/m.*

Sodic soils have high sodium.

- *High concentrations of sodium can result in soil dispersion.*
- *Drainage of saline/sodic soils without the addition of Ca can make the problem worse. In South Dakota an exchangeable sodium percentage above 5% is a cause for concern.*

Different testing laboratories analyze salt-affected soils differently.

- *Many soil testing laboratories use a 1:1 water to soil extract ratio, while NRCS and the United States Salinity Laboratory (where calibration of the response was initially conducted) uses the saturated paste method. Using a 1 to 1 extraction method typically results in a lower EC value than the saturated paste method. A 1:1 to saturated paste EC conversion table is shown in Table 48.2.*

Different plants have different salt tolerances.

Saline problems can be minimized by drainage, planting deep-rooted plants, and monitoring inputs and outputs.

Not all soils have the same risks. Soils that are coarse and soils that overlie shallow aquifers (less than 15 feet to the aquifer) have significantly less risk.

Salt problems, natural or man-made

Saline soils are those that contain high concentrations of soluble cations and anions (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}, SO_4^{-2}, NO^{3-1}, Cl^{-1}), while sodic (Na^{+1}) soils are those that contain high concentrations of sodium. High salt concentrations can result from weathering of soil minerals or an unintended byproduct of agricultural management. Minerals that may contribute to high salt concentrations include table salt (NaCl), baking soda ($NaHCO_3$), gypsum ($CaSO_3$), and calcite ($CaCO_3$). In saline soils, seed germination or plant growth can be reduced, while in sodic soils water infiltration can be reduced and emergence of seedlings can be impaired. Saline (high salts) and sodic soils require different management practices. Salt accumulation in South Dakota soils can result from interactions among management practices that impact local hydrologic cycles and natural processes.

Soils with salt problems can result from the weathering of soil and geologic parent materials, management, or a combination of both. A generalized saline risk map is provided in Figure 48.1. However, salt problems are not limited to high risk areas on the map. Within a field, salt has the potential to accumulate in some areas and not others. Generally, poorly drained areas have a higher potential to have higher salts than well drained areas. The lack of subsoil drainage and periods of above normal precipitation (or management that conserves water, such as summer fallowing and no tilling) often contribute to rising water tables.

When water tables rise to within several feet of the surface, ground water, through capillary rise, may be transported to the soil surface where it evaporates or is transpired. When this happens, pure water is evaporated and/or transpired leaving the salts behind. These conditions will result in elevated salt concentrations. High salt concentrations can reduce seed germination and yields. In many South Dakota fields, salt accumulation is not a problem. This is especially true if irrigation water is not applied and/or if the water table is deeper than six feet.

Saline (salts) and sodic problems can also result from irrigating with low quality (high salt content) irrigation water. When irrigation water is applied to soils, the water is used by the plants leaving the salts behind. Over a period of time these salts accumulate. These salts can reduce seed germination, plant growth, and yields. Before developing a remediation program it is important to determine if the problem is the result of high salts (saline) or high sodium (sodic soil).

Using a saline remediation program on a saline soil or vise versa produces adverse consequences:

> *In saline soils (high salts)* salts can be removed from the soil by: 1) installing tile drainage; and 2) using irrigation water in excess of the plant requirement, to leach salts from the soil surface.
>
> *In a sodium soil*, a remediation program might consist of: 1) installing tile drainage; 2) applying gypsum to the soil surface; and 3) using high quality water (low salts and sodium) to leach Na from the soil surface.

Figure 48.1. A map of the Northern Great Plains soils with a high risk potential for excessive soil salinity. Soils with EC> 4 dS/m constitute the high risk areas. (Source: http://www.soilsci.ndsu.nodak.edu/DeSutter/TomDeSutter.html)

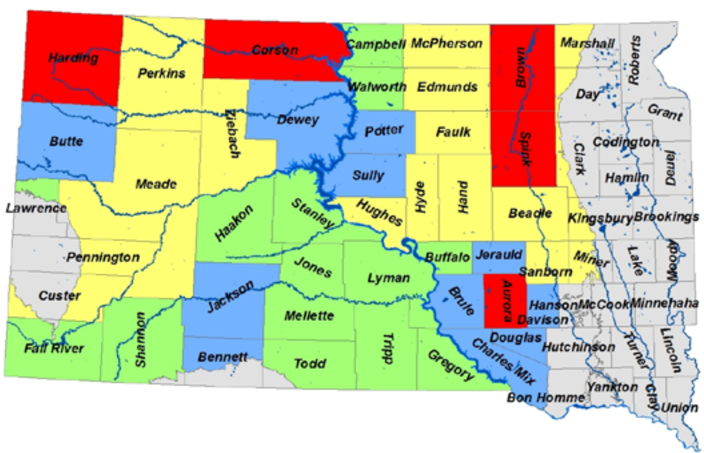

Figure 48.2. The percentage of sodic soils in South Dakota. In this map yellow is 10-20%, blue is 5-10%, green is 1-5%, and red is 20-30% sodium-affected soils. (Modified from Millar, 2003, http://www.sdnotill.com/Newsletters/2003_Salt_Soils.pdf)

Measurement

Many different approaches are used to measure salinity (salts). Salinity can be measured in the field with an EM meter (Geonics) or with a Veris Soil EC Mapping System. Both of the systems measure apparent EC (EC_a). Because both systems measure EC in the field, their measurements are influenced by soil water and bulk density. As the soil dries, EC_a decreases. In addition, soils with very high bulk densities or compacted layers can have very high EC_a values.

In the laboratory, EC is typically measured on water using a saturated paste extraction or a 1:1 soil/water solution. Most saline soil remediation protocols, including South Dakota, are based on saturated paste values, while most soil testing laboratories conduct a 1:1 soil/water test. A saturated paste is made by adding water to soil until it glistens and flows slightly when jarred. After allowing the mixture to equilibrate, the soil water solution is extracted by suction filtration. The electrical conductivity (dS/m) of the water is then measured.

Using a 1:1 test on saturated pasted recommendations can result in serious errors. For example, the EC of a soil sample determined by a local soil testing laboratory is 2 dS/m. Based on this value, you determine that raspberries (sensitive plant, Table 48.3) will have a minimal yield reduction. Based on this assessment you recommend that the producer plants ten acres of pick-your-own raspberries. Two years later the producer comments to you that the raspberries died and that he (or she) planted the field with organic wheat, which did well.

The error in this assessment was that 1:1 soil test value was not converted to a saturated paste value. When converted, the 2 dS/m is converted to value ranging from 5 to 6 dS/m (Table 48.2). This example shows that prior to making recommendations, 1:1 EC values must be converted to saturated paste values (Table 48.2). According to Franzen (2007), the equations relating EC using a 1:1 soil to water extraction ratio are different for coarse (sands), medium (loams), and fine (clay) textured soils.

The equations for these soils are:

Coarse soil: $EC_{\text{saturated paste}} = 3.01 \times EC_{1:1} - 0.06$

Medium: $EC_{\text{saturated paste}} = 3.01 \times EC_{1:1} - 0.77$

Fine: $EC_{\text{saturated paste}} = 2.96 \times EC_{1:1} - 0.95$

Table 48.2. The relationship between EC measured using the 1:1 and saturated paste techniques. (Modified from Franzen, 2007)

EC 1:1	Saturated Paste EC		
	Course (sand)	Medium (silt loam)	Fine (clay)
dS/m	dS/m		
1	3	2.2	2
2	6	5.3	5
3	9	8.3	7.9
4	12	11.3	9.4
5	15	14.3	13.9

Impact on plants

Different plants have different tolerances to saline conditions (Fig. 48.3). A detailed list of plant salt tolerances is available at http://www.fao.org/DOCREP/005/Y4263E/y4263e0e.htm. A shortened list is provided in Table 48.3. Soybean is considered a moderately tolerant plant and has an EC saturated paste threshold value of 5.0 dS/m (Fig. 48.3; Maas, 1984). For moderately tolerant plants such as soybeans, each 1 dS/m increase above 5 dS/m results in a 20% yield loss. In addition to restricting plant growth, saline soils can restrict seed germination. Many plants have different tolerances for seed germination than for growth. For example, alfalfa has a low tolerance for seed emergence and moderate tolerance for plant growth.

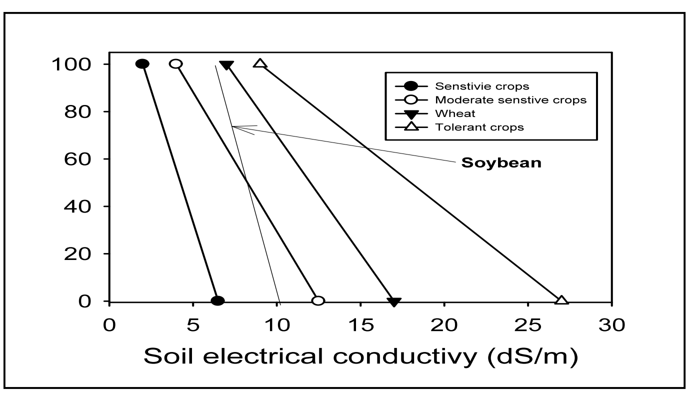

Figure 48.3. Relative crop yield potential as a function of soil salinity. (Developed from data by E.V. Mass, 1984)

Table 48.3. A list of salt tolerances of selected plants. (Modified from Franzen, 2007)

Salt Tolerance	Plants			
Sensitive	Beans	Carrots	Strawberry	Onion
Moderately sensitive	Alfalfa	Corn	Flax	Cucumber
Moderately tolerant	Oats	Sorghum	Soybean	Sunflower
	Wheat	Squash		
Tolerant	Barley	Canola	Sugar beets	Durum wheat

Mapping soil salinity within a field

Several approaches can be used to assess the extent of salt problem. The first approach is targeted soils sampling. Areas that appear white as they dry often have high salt concentrations. An alternative approach is to map a field with either a Veris Technologies EC cart (http://www.veristech.com/products/soilec.aspx) or a Geonomics EM 38 (http://www.geonics.com/html/em38.html) meter. These systems measure apparent EC because the readings are sensitive to many factors including salt concentration, bulk density, and soil water content.

Salinity management: Drainage

High salinity is often a symptom of a high water table. Drainage can be used to reduce salinity risks. On average, the soil EC value will decrease 0.5 dS/m for every six inches of water that percolates through the soil.

For tile drainage to be effective, a suitable outlet for the drainage water must be available. There are many places in South Dakota where surface drainage outlets are not available. In addition, there are drainage laws that require producers to work with local authorities and USDA-NRCS. Details about tile drainage are provided in Chapter 47.

Salinity management: Cover and deep-rooted plants

In some situations, perennial deep-rooted crops, such as alfalfa, can also be used to lower the water table and reduce salinity problems. Alfalfa may not germinate in the saline area, but seeding in strips several hundred feet wide in non-saline areas just above the saline spot may be effective in reducing the water table. Seeding a salt-tolerant crop such as Tall Wheat grass or barley within a salinity pocket may also be effective in lowering the water table. Cover crops seeded in the fall may be used to reduce the water table. Lowering the water table reduces capillary rise and provides the opportunity for salts to leach.

Tillage in saline areas

In South Dakota there is a significant opportunity for salt leaching from fall, winter, and spring precipitation, assuming the water table is not close to the soil surface. Deep tillage or ripping should be used with caution because it has produced inconsistent impacts on salt concentrations. Spring tillage has the potential to reduce seed germination by moving salts leached during the fall and spring to the soil surface. For many fields with adequate natural and tile drainage, techniques that reduce surface soil evaporation, such as no-till and minimum till, have been used successfully.

Soil amendments for saline areas

A saline soil has a high concentration of total salt. The application of materials such as gypsum (calcium sulfate) will not resolve the salt issue. In fact, gypsum is a salt and therefore its addition may make the problem worse.

Figure 48.4. A sodium-affected surface soil. (Photo courtesy of C. Gregg Carlson, SDSU)

Sodium-affected soil

Sodium (Na) is a salt that requires special attention (Figs. 48.2 and 48.4). High concentrations of sodium on the soil exchange complex when combined with low salt concentrations in the soil water solution can destroy the soil structure. Soils with high Na concentrations will be cloddy with poor infiltration. Drainage of high Na soils without adding an appropriate surface treatment ($CaCl_2$, $CaSO_4$, or elemental S) is very risking. Many tile-drained fields fall into this category. If drainage through tile lines appears to be slowing with time, you may be at risk. It is important to point out that an analysis of the tile-drained water does not provide an accurate assessment of the Na risk in the surface soil.

Problem 48.1. Sample calculations for determining SAR values.

A soil sample is sent off to a laboratory for analysis. In this analysis a saturated paste (approximately 100g soil + 60 ml water) is made and equilibrated for 24 hours. The water is extracted by vaccum and the Na, Ca, and Mg determined. The water analysis of a soil/water saturated paste is 2136 ppm Na, 2181 ppm Mg, and 3198 ppm Ca. SAR is calculated below.

A list of laboratories that could conduct the analysis is provided in Chapter 18.

Answer to Problem 48.1.

Note: When doing this calculation, it is important to know that Na has a valance of +1, Ca has a valance of +2, and Mg has a valance of +2. The valances are used to convert mmol to mmolc.

Step 1. Convert ppm to mmolc/L. For this conversion 1ppm = 1 mg/L

$$\frac{\text{Na mmol}_c}{\text{L}} = \frac{\mathbf{2136}\text{ mg Na}}{L} \times \frac{\text{mmol Na}}{\text{23 mg Na}} \times \frac{\text{1 mmol}_c\text{ Na}}{\text{1mmol Na}} = \frac{\text{92.9 mmol}_c}{\text{L}}$$

$$\frac{\text{Mg mmol}_c}{\text{L}} = \frac{\mathbf{2180}\text{g Mg}}{L} \times \frac{\text{mmol Mg}}{\text{24.3 mg Na}} \times \frac{\text{2 mmol}_c\text{Na}}{\text{1mmol Na}} = \frac{\text{179.3 mmol}_c}{\text{L}}$$

$$\frac{\text{Ca mmol}_c}{\text{L}} = \frac{\mathbf{3198}\text{g Na}}{L} \times\times \frac{\text{mmol Na}}{\text{40 mg Na}} \times \frac{\text{2 mmol}_c\text{ Na}}{\text{1mmol Na}} = \frac{\text{159.9 mmol}_c}{L}$$

Step 2. Calculate SAR

$$SAR = \frac{\frac{mmol_c Na}{L}}{\left(\frac{(mmol_c Ca / L + mmol_c Mg)}{\mathbf{2}}\right)^{\mathbf{0.5}}} = \frac{\mathbf{92.9}}{\left(\frac{(\mathbf{179} + \mathbf{160})}{\mathbf{2}}\right)^{\mathbf{0.5}}} = \mathbf{7.1}$$

The sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) are two calculations used to estimate Na risk. Both calculations provide estimates of the relative amount of Na contained in the soil. Due to cost, most recommendations are based on the SAR value. If a Na problem is suspected, a soils specialist should be contacted for advice. In dryland agriculture, the drainage of soils with sodium adsorption ratios greater than five, without the addition of Ca or lowering the pH, can result in soil dispersion. Sample calculations to determine the soils SAR are shown in Problem 48.1.

Reclamation of sodium-affected soils

As a rule of thumb, South Dakota soils should not exceed a sodium adsorption ratio (SAR) (~exchangeable sodium percent, ESP) value of five. The reclamation of sodium soil is slow because it can take a long time to rebuild the structure. One relatively inexpensive approach to improve the soil structure is to apply low Na containing manure or to apply crop residues to these areas. The organic matter in these materials can help stabilize and improve soil structure. It must be pointed out that not all manures have low Na concentrations.

Manure from animals that have high concentrations of NaCl in their rations may not be desirable. For example, 1) distillers grains from ethanol plants may be treated with sodium chloride; and 2) swine, poultry, and beef have diets that are often supplemented with NaCl. Many animals have diets supplemented with NaCl because the plant materials do not provide enough Cl or Na to meet the animals' nutritional requirement.

A second approach is to replace the Na on the soil exchange site with calcium. For this treatment, $CaCl_2$ is often the most effective materials. However, it also is very expensive. A less expensive Ca source is gypsum ($CaSO_4 \cdot 2H_2O$). **For a typical South Dakota soil with a cation exchange capacity (CEC) of 25 cmolc/kg and a SAR value of twelve, a one-ton application of gypsum per acre would be needed to lower the SAR value of the surface six inches to eight.** To lower the SAR value to four, about two ton/acre of gypsum are needed. For this calculation, the CEC can be estimated from the organic matter and clay contents of the soil (Fig. 48.6). Sample calculations follow:

Problem 48.2. A soil contains 3% organic matter and 20% smectite clay. What is its estimated cation exchange capacity (Clay et al., 2011)?

Soil component	CEC
Organic matter	$\frac{200\ cmol_c}{kg\ soil}$
Smectite clay	$\frac{100\ cmol_c}{kg\ soil}$

$$\text{Cation Exchange Capacity} = \frac{\%\ \text{clay}}{100} \times CEC_{clay} + \frac{\%\ \text{Organic matter}}{100} \times \text{CEC}_{\text{organic matter}}$$

$$\text{Cation Exchange Capacity} = \frac{20\%}{100\%} \times \frac{100 cmol_c}{kg} + \frac{3\%}{100\%} \times \frac{200 cmol_c}{kg} = 26 cmol_c / kg = 26 mmol_c / 100g$$

Calcium can also be released by lowering the pH. The soil pH can be lowered by adding elemental sulfur. To increase the effectiveness of elemental S it should be mixed into the soil. The amount of S that needs to be applied can be calculated from data provided in Table 48.4. To displace the Na from the soil exchange site, good quality water must be added.

Table 48.4. Relative amount of different soil amendments needed to reduce Na on the exchange site. Rates for alternative substances determined by taking recommended amount of Gypsum times base amount of alternate substance.

Recommended Amount of Gypsum tons/acre	Amount of $CaCl_2$ tons/acre instead of Gypsum	Amount of Elemental S tons/acre instead of Gypsum	Amount of Aluminum sulfate tons/acre instead of Gypsum
1.00	0.85 (base)	0.19 (base)	1.29 (base)
1.5	1.28	0.29	1.94
2.0	1.7	0.38	2.58

Summary

Saline (high total salts) and sodic (high sodium) must be managed differently. In managing saline and sodic soils, care must be used to prevent further degradation.

In saline soils, recommended practices include:

- ▹ Collect soil and water samples to identify the scope and magnitude of the problem.
- ▹ Analyze the soil samples for both EC and SAR.
- ▹ Convert 1:1 EC values to saturated paste values (Table 48.2).
- ▹ Track changes in EC and SAR over time.
- ▹ Seed salt tolerant plants.
- ▹ Treat soil with crop residues to increase water infiltration.
- ▹ Eliminate sources of new salt.
- ▹ Use practices that reduce surface evaporation.
- ▹ Provide subsurface drainage.

In sodic soils, recommended practices include:

- ▹ Collect soil and water samples to identify the scope and magnitude of the problem.
- ▹ Analyze the soil samples for EC and SAR.
- ▹ Track changes in EC and SAR over time.
- ▹ Seed full season, deep-rooted plants.
- ▹ Eliminate sources of new Na.
- ▹ Use practices that reduce surface evaporation.
- ▹ Minimize the use of tillage, which brings Na to the soil surface and reduces residue cover.
- ▹ Eliminate fallow.
- ▹ Apply crop residues to increase infiltration.
- ▹ Provide subsurface drainage and treat with a Ca source such as gypsum.

Salt problems are often discovered in low elevation areas. In the spring as the soil dries, these zones may appear white. In these areas, water and the salts dissolved in the water rise through capillary movement from the water table to the surface. As the water evaporates at the soil surface, it is replaced by more water from the water table. The net result is an accumulation of salts. This net gain of salts can be reduced by installing tile drainage; planting full season, deep-rooted plants; and eliminate fallow. The most important management consideration for these areas is to maximize transpiration and minimize evaporation (Franzen, 2007).

For sodic soils, extreme care must be used. High sodium has the added problem in that it can greatly reduce water infiltration. If a sodium problem is suspected, a soil sample should be collected and a water extract from that soil analyzed for Na, Ca, and Mg. Based on this value, the SAR should be calculated. If sodium is a problem, the SAR is greater than 5-8, then a long-term goal should be to prevent further degradation. This can be accomplished by tracking changes in the EC and SAR values of the soil, installing tile drainage, adding low Na manure or gypsum, or lowering the pH (if the soil pH is high) with elemental S. If drainage and soil amendments are not possible, consider placing the field into pasture and planting it with salt-tolerant grasses.

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